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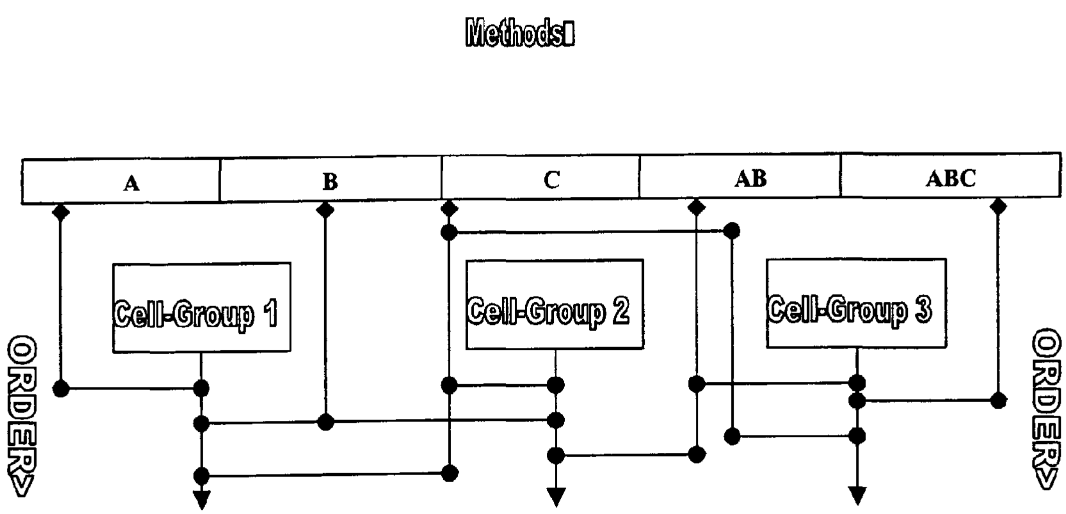
**(54) Title:** METHOD RELATING TO POSITIONING OF A MOBILE DEVICE




**(57) Abstract:** The present invention relates to a method of estimating the position of a mobile station in a cellular network, comprising a serving cell and neighboring, cells, the method comprising the steps of : employing different sub-methods to estimate an actual position of the mobile station, said submethods comprising at least two of: selecting a center of a cell, selecting an intersection of a cell, a middle point of a position in cells, taking an action when no intersection between the serving cell and the a best cell occurs, combining said sub-methods with each other with respect to a size of a serving cell, dividing the size of said serving cell in a number of different sectors, based on a number of pixels, which every cell is made of a number of pixels, and selecting the best sum-methods for each cell-group.

*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

# METHOD RELATING TO POSITIONING OF A MOBILE DEVICE

## Technical field of the invention

The present invention relates to a method of estimating the position of mobile station in a cellular network, comprising a serving cell and neighboring cells.

## Background of the invention

Today, the importance of GSM is increasing on a daily basis. Beside the increased usage of mobile phones, there are other areas where GSM can be used. One of those areas is mobile positioning. Mobile positioning centre is a flexible link between commercial as well as security-related applications and the world of positioning. There is a number activities in this area today. The United States Federal Communications Commission (FCC), for example, requires that, by year 2001, all mobile communication networks should be able to locate a caller's mobile unit requesting emergency assistance. There are several other areas where mobile positioning systems can be used. The advantage of mobile positioning systems is that the existing telephony network can be used to obtain the positioning. Another reason that makes GSM-positioning so attractive is that GSM delivers lots of information and this information can be used in different positioning algorithms. Even from the emergency assistance' point of view, the GSM-positioning is of great interest. Because the usage of cellular phones by ordinary people in case of emergency, one can only be found by tracking his/her mobile phone.

There are many companies and research centers, all around the world, working on this issue. Many make serious attempt to develop positioning methods that fulfill the market expectation.

Most of the researches that have been done are based on redesigning the Base Transceiver Station (BTS) to collect more information from the mobile station. Positioning by GSM can be classified in three different parts, *self-positioning*, *remote-positioning* and *indirect-positioning*.

*Self Positioning:*

In the self-positioning case, the positioning receiver makes all the appropriate signal measurements from geographically- distributed transmitters and uses this measurement to determine its position.

*Remote Positioning*
In remote positioning, signals from the object to be positioned are measured from different receivers and sent to a central site where the position of the object will be determined.

*Indirect Positioning*
In this case, the appropriate signal measurement from a self-positioning receiver will be sent to a remote site for determination of the receiver's position.

Moreover, there are many different ways to position a mobile station. The most important measurement techniques are propagation time, Time Difference Of Arrival (TDOA), Angle Of Arrival (AOA) and carrier phase. Among these positioning techniques, there is a point at which the loci from multiple measurements intersect defines the position of the mobile station. If there are less then two measurements available, the loci will intersect in more than one point and it will cause ambiguous position estimation.

*Propagation Time:*
In propagation time measurement, the round-trip time of a signal traveling between the mobile station and the base station and vice versa will be measured. Therefore, the receiving base station(s)/ mobile station must know exact time when signal(s) has or have been transmitted and the receiver(s) should have a very stable and accurate clock. Each measurement then results in a circle around the base station, where the mobile station (the object being positioned) should lie on the locus of it. The intersection of these circles determines the actual position of the mobile station.

*Time Difference Of Arrival (TDOA):*
In Time Difference Of Arrival, the mobile station measures the time difference of arrival from a pair of base stations. For example, in the case of three base stations, the mobile station measures two independent TDOA measurements. Each TDOA measurement defines in a hyperbolic locus on which the mobile station must lie. The intersection of the two hyperbolic loci determines the position of the mobile station.

The above example describes a self-positioning algorithm. In case of remote positioning, it is the base stations that listen to the mobile stations and records the time of arrival (TOA). The result then will be sent to the central site for evaluation and to estimate the position of the mobile station.

*Angle Of Arrival (AOA):*

Angle Of Arrival (AOA) measures the angle of arrival of a signal from a mobile station at a base station or vice versa. In both cases, a signal measurement produces a straight line from the base station to the mobile station. The intersection of these lines determines the position of the mobile station. The advantage of Angle Of Arrival is that there is only a need of two base stations to do the measurement without having problem with the ambiguity.

*Carrier Phase:*

The phase of a carrier has the potential of providing the position estimations with an error less then the carrier wave- length. Instead, there will be a large number of ambiguities that arise in the positioning estimation. The positioning receiver can measure the phase of the received signal but it cannot measure the integer number of the cycles (wavelength) between the transmitter and the receiver. The other problem with carrier phase is to maintain a continuous lock on the carrier signal. Failure to do so, results in cycle slips and positioning errors.

There are several different physical architectures that could be used for positioning in GSM such as: mobile-based, network-based and hybrid positioning. The needs of a given positioning application will determine where the position information is required, the position update rate for each object being tracked, the number of objects to be tracked, and the value of the position information. Following is a brief review on these architectures.

Mobile-Based Positioning is defined here as the case where the mobile station using downlink information from the BTS to determine its position. This case is a form of self-positioning. In order for the mobile station to determine its position, there are a number of techniques, but the basis is likely to be TDOA. There are two fundamental modifications, which need to be made to GSM equipment. The first one is to modify the mobile station to be able to do TDOA measurements. Such measurements will use algorithms to reject multi-path. By processing the burst information to locate the epoch of training sequence, the TDOA can be determined. The

simplest logical channel on which to this processing is carried out, is the Broadcast Control CHannel (BCCH). Because the bursts are not subject to frequency hopping and power control and it is repeated more frequently then the SCH channel.

The second modification must be done to synchronize the network. There are two options the first one is to tightly synchronize the base stations. There are a number of ways of doing it, one of them is to place a GPS time transfer receiver at each base station.

The other option is to provide information to the mobile station by monitoring receivers, which measure the timing offset between different base stations. Using Short Message Service (SMS) or a paging service, this timing data can be sent to the mobile station.

Network-based positioning is based on using transmitted data from the mobile station to determine the position of the mobile station. This way of positioning is a form of remote positioning. The simplest implementation of network-based positioning of GSM is to be based on a TDOA approach. In this case, a number of base stations around the mobile station will monitor the uplink data from the mobile station and make a TOA measurement of the signal from the mobile station. Different TOA measurements will eventually reach the Location Service Center (LSC). The LSC will generate TDOA measurements from the received TOA data and subsequently produce a position estimate.

***Hybrid Positioning***

Hybrid positioning architecture combines different aspects of both mobile-based and network-based positioning. Possible hybrid architecture could be designed as described below.

The mobile station requires measurement information from the base stations that has been referred to for determination of the TOA measurements. This information will then be sent to a Local Service Center (LSC) for TDOA measurements and eventually for determination of the mobile station.

However, the method that is used to position a mobile station is different than the above-described methods.

As it appears, in all these methods, a modification of the Base Transceiver Station (BTS) and/or the mobile station is necessary. This method is basically based on the wave propagation data or prediction data.

The prediction data covers a certain area. Each part of this area belongs to a certain BTS. This area is presented as a discreet amount of points called pixels. Each pixel has it own BTSs with a unique Cell Identification number, here called Cell-ID, for every one of them. By using the same information from the mobile station, this can be available by manipulating the SIM-card, when positioning is desired and compare this information with the prediction data in a certain way that a positioning can occur.

The benefits of this method are numerous. By having prediction data that covers the area of interest and manipulates the SIM-card of the mobile station, positioning can be done. This will have a minimal cost and by placing the positioning information inside a database, the positioning speed will increase prominently.

The only source of information available is on the SIM-card inside the mobile station. The only available information here is that the cell-IDs form the BTSs around the mobile station. The mobile station detects cell-ID from a serving cell, which is covered by a specified BTS. It also detects several other cell-IDs. The mobile station uses these cell-IDs to find itself in the area in case of handover. Beside the cell-IDs there is also the RX-level (Control Power Level) belonging to each cell. This information alone is far from enough for a positioning algorithm, but the propagation data and the available information on it provides a possibility. Considering the prediction data, each cell combination with, e.g. five involved cells, is combined with a pixel. The pixels are positioned in X- and Y-coordinates. The serving cells cover the area completely covered by prediction data, in other words, every pixel in the coverage area has its own serving cell. The distance between two nearest pixels can for example be one hundred meters. At each pixel, there are always, for example four other cell-IDs, beside the serving cell, in case of handover execution.

The first step is to find out the correlation between the serving cell in a sample data regarding the prediction data. This means to find out if the serving cell for each sample is the same in the prediction data regarding the coverage area of the serving cell. This could be done by determining, if the difference in distance, regarding the area that the serving cell from each

sample covers in the prediction data. This distance between the position of the sample and the nearest pixel in the prediction data regarding the serving cell coverage area must be less than a threshold value, e.g. 75 meters. The result should probably be more than 50%. Even correlation between the second best cell and the third best cell in the sample data regarding the prediction data would be of great interest. The border area (Gray zone) between different cells is another issue that can be considered. The serving cell size, the size of the area considering the intersection of the serving cell, the second best cell and/or the third best cell can be of interest, too. After all this measurement analysis and verification, it will be time to find out an algorithm based on this information to get the best estimated position for the samples.

The main problem is the lack of sufficient parameters to handle. As mentioned earlier, the only information that is available is the serving cell, other best cells in case of handover and their RX-levels. The other source of information is the prediction file, which gives the predicted position of the coverage of each cell. The RX-levels are very unreliable sources and the only benefits are to find out the order in which the cells are available in case of a handover. It is also interesting sort the levels in different RX-groups. The interesting parameters are the cell coverage area of each cell in the prediction data and its relation with the collected samples.

In order to obtain a reasonable estimation, the error sources are considered. Firstly, in the prediction file, there is a distance of about one hundred meters (in this case) between the pixels. This will give a maximum error of about 75 meters in distance. Secondly, the mobile station uses the same algorithms to find out its serving cell as the prediction data has been based on measuring its serving cells. The difference is, firstly the geographical properties; for example: a construction building is going on in the area or some very large vehicle in the way of the wave propagation field. The second reason could be the mobile traffic in the area. In both cases, the mobile station could detect some other cell as the serving cell and/or other best cells than it should detect. In these cases, the data from the prediction file will be uncorrelated regarding the sample. Collection of samples can cause errors in distance too. The position at which the sample is taken becomes, in some cases, manual by reading the position from a map that may give an error of for example 5 to 10 meters. Another way of collecting samples is to use a GPS (Global Positioning System) navigator. This method gives a maximum distance error of 40 meters. However, this positioning method is of less interest because in areas covered by microcells (cells with small area coverage), for example, in urban areas, no appropriate data for positioning is obtained.

Another important issue is the multipath phenomena. In a mobile radio transmission, when uplink or downlink, the transmitted signal is usually reflected from surrounding buildings, hills, and other obstructions. As a consequence, a multiple propagation path arrives at the receiver at different delays. This phenomenon is called multipath. Because of the multipath, not all data in the prediction file can be used in the analysis. In the prediction file, the multipath has been taken under consideration in case of the cell coverage. When an area on the prediction file has been detected, the direction from the BTS toward that area is not the direction from the BTS toward the mobile station because of the multipath.

As it appears, the prediction data is the important part of the analysis and every measurement and estimation will be done according to it.

In WO 99/46947 a telecommunications system and method is disclosed for allowing a cellular network to determine the optimum positioning method, having knowledge of all available network-based and terminal-based positioning methods. This can be accomplished by the Mobile Station (MS) sending to the Mobile Switching Center/Visitor Location Register (MSC/VLR) a list of terminal-based positioning methods that the MS is capable of performing. This list can, in turn, be forwarded to the Mobile Positioning Center (MPC) for determination of the optimum positioning method. For example, in a GSM network, the MS CLASSMARK information, which is sent to the MSC/VLR when the MS registers with the MSC/VLR, can be extended to include the MS's positioning capabilities.

According to WO 94/27398 a cellular telephone system includes a plurality of cell sites and a mobile telephone switching office (MTSO). Call management, including selection of a cell site most appropriate for a call associated with a mobile unit are made based on the geographic location of the mobile unit as opposed to the strength of the signal associated with the call. The geographic location of the mobile unit is precisely determined using triangulation, a NAVSTAR global positioning system, or its equivalent. Each mobile unit includes a GPS receiver that receives information from a geostationary satellite to determine the precise location of the mobile unit. This position information is relayed to the cell site initially managing the mobile unit, and the mobile unit is handed off to a cell site that is most appropriate for the call. Initial selection of an entrance cell site is made based on signal strength, but further call management decisions are made based on location of the mobile unit.

## Summary of the invention

One object of this invention is to provide a method to estimate the best position of a mobile station based on the cell-ID(s) that has/have been detected by the mobile station. In order to give each cell-ID and each cell-ID combination an estimated position and use it as a database, it can be used as a complement to other positioning algorithms and systems.

It will then improve the original positioning algorithm and estimate a better position of the mobile station.

This method is based on estimating the position of a mobile station by looking for the mobile station in a certain area, where the possibility of it being there is the highest. It can be done using the wave propagation data, which the operator uses to plan the cell distribution.

Thus, the present invention relates to a method of estimating the position of a mobile station in a cellular network, comprising a serving cell and neighboring cells, the method comprising the steps of: employing different sub-methods to estimate an actual position of the mobile station, said submethods comprising at least two of: selecting a center of a cell, selecting an intersection of a cell, a middle point of a position in cells, taking an action when no intersection between the serving cell and the a best cell occurs, combining said sub-methods with each other with respect to a size of a serving cell, dividing the size of said serving cell in a number of different sectors, based on a number of pixels, which every cell is made of a number of pixels, and selecting the best sub-methods for each cell-group.

## Short description of the drawings

In the following, the invention will be further described in a non-limiting way with reference to the accompanying drawings in which:

Fig. 1 is a block diagram over a system incorporating the present invention,

Fig. 2 schematically illustrates a cell coverage scheme, and

Fig. 3 is a block diagram representing the method of the invention.

**Detailed description of the embodiments**

As it has been describe before, the prediction data covers a certain area and divides it into different sectors, belonging to different cells. Each cell that covers a certain area has intersections with other cells. The area can be represented by pixels. The distance between the two closest pixels is, for example one hundred meters. For each pixel beside the cell-ID of the serving cell, there are also four other cell-IDs. These cells are needed in case of handover. For each cell-ID, there are data on power control level and distance from each cell to the pixel, e.g. in form of polar coordinates.

The data in raw condition needs to be prepared for processing, e.g. by converting it into matrix form (it may contain some irrelevant information that must be removed). Through processing of the data, the information is obtained for each pixel of the area that the prediction file covers in several rows and mixed data and text. It is necessary to consider the edges of area covered by the prediction file. The cells involved in those areas, which are not fully inside the coverage area of the prediction data must be excluded, because of the size of the cells. The cell size is one of the basic parts of the positioning.

Samples are data collected by finding out the position of a mobile unit and the information on the serving cell and other available cells that the mobile station uses in case of handover. There are different kinds of methods to do so. One way is to use a *differential GPS-navigator* combined with a GSM positioning unit. This will automatically provide the position and the information on the cells regarding that position for a mobile unit. Differential GPS-navigator has an accuracy of 4 meters only.

Data samples mainly consist of three different parts: The position of the mobile unit; Cells indicated by the positioning unit and the RX Level for each cell.

The available information received from the mobile station are the cell-ID of the serving cell and between one to six other cell-IDs depending on the area form which the measurements have been collected. The mobile station, in case of handover, uses these cell-IDs. The RX Levels (Power Control Levels) are also available for each cell-ID. This information is then compared with the prediction data in order to make different algorithms.

Firstly, the ability of the prediction data has to be taken under consideration. Because of the nature of the prediction data when a sample indicates a series of cell-IDs, the position of the sample has to be inside the coverage area by the same combination of cell-IDs indicated by the prediction data. However, in reality, that is not the case. Because of the error sources, the cell-IDs that the mobile station delivers are not the theoretical cell-Ids, which are expected regarding the position of the mobile station. It is better to look at each indicated cell-ID by the mobile station with regard to its rank (the serving cell, second best cell, etc.) and compare it with the prediction data. In order to do so, a classification of the serving cell, second best cell, and so on, concerning their ability, could be possible.

The serving cell should have the best ability; in other words, most of the position samples should be inside the area covered by the indicated serving cell from each sample data in the prediction data. The second best cell then would be the next most reliable cell and the third best cell would be the best after that.

The other indicated cells such as the fourth best cell, etc. does not give any reliable information and can cause even more confusion. It is better not to consider them at all, at least for the time being. In case of the RX Levels, it appears to have the same effect as the information from the fourth best cell, etc. It is much better to concentrate on the three best cells: the serving cell, the second best cell; and the third best cell, in the beginning, and find an algorithm based on them.

Based on the argument above, all methods are based on the information available on the first three best cells when it is available.

The first step to reach a positioning method is to make a number of different methods (sub-methods) to estimate the actual position of a mobile station. The next step will be then to combine these sub-methods with each other regarding the size of the serving cell. The size of the serving cell can be divided in three or for different sectors. These sectors are chosen based on the number of pixels, which every cell is made of. For example, a cell that covers an area of $1km^2$ is made of 100 pixels.

The last step is to choose the best sub-methods for each cell-group. In order to have a better comprehension on this; a graphical scheme illustrating this method is illustrated in fig. 3.

In order to find out relevant methods there is a need for a method of analyzing the characteristic of samples in more detail. One method is based on analyzing the position of any chosen sample regarding its serving cell, second best cell, third best cell as well as their intersection.

A number of sub-methods can be produced by analyzing the samples and finding out a pattern of the correlation between the cells and the position of the mobile station,. Next step is a method that only shows the position of the sample and the estimated position regarding those different methods.

By analyzing these methods compared to the sample position, new sub-methods can be estimated. Following is the results:

**Method A**
According to this method, the middle of the serving cell is selected as the estimated position of the mobile station.

**Method B**
According to this method, the middle of the second best cell is selected as the estimated position of the mobile station.

**Method C**
In this method, the middle of the third best cell is chosen as the estimated position of the mobile station.

**Method AB**
In this method, when an intersection between the serving cell and the second best cell exists, the middle of this intersection is chosen as the estimated position of the mobile station.

**Method AC**
In this method, when an intersection between the serving cell and the third best cell exists, the middle of this intersection is chosen as the estimated position of the mobile station.

**Method ABC**

In this method, when an intersection between the serving cell, the third best cell (as the second best cell) and the second best cell (as the third best cell) exists, the middle of this intersection is selected as the estimated position of the mobile station.

**Method ACB**

In this method, when an intersection between the serving cell, the third best cell (As the second best cell) and the second best cell (As the third best cell) exists. The middle of this intersection is chosen as the estimated position of the mobile station.

**AB_**

In this method, when no intersection between the serving cell and the second best cell occur. The middle of the two nearest pixels between the serving cell and the second best cell is choose as the estimated position of the mobile station.

**ab_**

In this method, when no intersection between the serving cell and the second best cell occurs, the middle of the nearest pixel in the second best cell regarding the serving cell and the middle of the serving cell is chosen as the estimated position of the mobile station.

**AC_**

In this method, when no intersection between the serving cell and the third best cell occurs, the middle of the two nearest pixels between the serving cell and the second best cell is chosen as the estimated position of the mobile station.

**ac_**

In this method, when no intersection between the serving cell and the third best cell occurs, the middle of the nearest pixel in the second best cell regarding the serving cell and the middle of the serving cell is selected as the estimated position of the mobile station.

**AB|AC**

In this method, middle point of the position in AB and AC is chosen as the position of the mobile station.

**A|AB**

In this method, middle point of the position in A and AB is selected as the position of the mobile station.

**A|AC**

In this method, middle point of the position in A and AC is chosen as the position of the mobile station

**AB_|AC_**

In this method, middle point of the position in AB_ and AC_ is chosen as the position of the mobile station.

**AB_|ab_**

In this method, middle point of the position in AB_ and ab_ is selected as the position of the mobile station.

**AB_|ac_**

In this method, middle point of the position in AB_ and ac_ is chosen as the position of the mobile station

**AC_|ac_**

In this method, middle point of the position in AC_ and ac_ is selected as the position of the mobile station

**AC_|ab_**

In this method, middle point of the position in AC_ and ab_ is chosen as the position of the mobile station.

**ab_|ac_**

In this method, middle point of the position in ab_ and ac_ is selected as the position of the mobile station.

**A|AB_**

In this method, middle point of the position in A and AB_ is selected as the position of the mobile station.

**A|AC_**

In this method, middle point of the position in A and AC_ is selected as the position of the mobile station.

**A(AB_|AC_)**

In this method, middle point of the position in A and AB_|AC_ is selected as the position of the mobile station.

**A-Bneig**

In this method, middle of A is chosen as the position of the mobile stations; only for samples there second best cell is close to the serving cell.

**AB-Bneig**

In this method, AB is selected as the position of the mobile stations; only for samples there second best cell is close to the serving cell.

**A-Cneig**

In this method, A is selected as the position of the mobile stations, only for samples there third best cell is close to the serving cell.

**AC-Cneig**

In this method, AC is selected as the position of the mobile stations, only for samples there third best cell is close to the serving cell.

**A-betweenB&C**

In this method, A is selected as the position of the mobile stations, when A is between B and C.

In all these methods, evaluating the mean of the section has provided the middle of a section. Some of the methods are represented schematically in fig. 3.

The result of these methods for all the samples can be collected in a matrix. This matrix contains the coordinates for each estimated position for all the existing samples for each method, the size of the indicated area (number of pixels involved) and the positioning error, see pseudo-code Result_Matrix in Appendix B. In order to position all sample data, a classification of the samples is necessarily.

There are several ways to classify the samples. However, the method, which has been used, is based on dividing the cells by the size of the serving cell for each sample.

Trying to find out different interval of the serving cell size can do this, e.g. by dividing the samples in different groups and study the behavior of the samples in each interval. This is done see pseudo-code Demo and stat2 in Appendix B. In this way the intervals can be set. Next step is to divide the samples in to different groups regarding these intervals.

The final step will be then to find out, which method is best in each group. The positioned samples will then be reduced form the samples belonging to the cell-group, same procedure will be repeated until all samples are positioned. The pseudo-code for a method is involved in this process is Divide_Cell_size, in Appendix B.

When the ability of sub methods has been appointed, ALG1-4 Appendix B would position the samples.

There will be several ways of sorting cells in different groups regarding the cell size.

As mentioned above, it is necessarily to verify the ability of the prediction file. The prediction data contains data on cells that cover a certain area. This area is represented by a number of pixels with each pixel having information on which cells it belongs to. For each cell, there is information for the distance from the cell towards the pixel and the power control level at which the signal arrives to the mobile station. The sample has the same information as the prediction file. A sample consists of the coordinates at which the mobile station is at, a number of cell-IDs belonging to the cells that cover the area and the RX Level (Power Control Level) for each cell-ID. By counting the number of samples, which exist inside the coverage area of the cells they are indicated on, the ability of the prediction data can be set. Based on these measurements, the first step toward a positioning is taken. This information depends on how good the data from the

collected sample and the prediction data is correlated. Besides that, the limitation of the positioning algorithm can be set. The next step is to isolate certain areas regarding different cell combinations, if available, and estimate errors between the actual positions of the samples toward the estimated position by these methods. To see the improvement of these methods, they can be compared to the methods that are available. As it has been mentioned earlier, GSM-positioning is a new product and most companies that develop this kind of product do not provide others with their results. However, there are two different kinds of positioning devises available. One of the devises (GT-1 without TA) uses a "triangulation" method to estimate the position of the mobile station. The other devise (GT-1 with TA) uses Timing Advance to do the positioning.

Whenever something is to be measured, accuracy would always be involved. This case is not an exception but because of the roughness of the prediction data, the distance between two neighboring pixels is assumed to be 100 meters. Up to a few meters' error when the samples collected is not of any importance.

In order to make a complete positioning algorithm, it is necessary to put together all results that have been collected. By beginning to find out the ability of the tools and the basic data available could do this. Based on that, by building different sub-methods and putting them together in the right order, a good positioning algorithm could be made.

As mentioned earlier, the ability of the cells is the ground basis to start with. Here is the result on the cell ability. The values are shown in how many cases the mobile station finds itself in the coverage area of the cell at which it is indicated regarding the prediction data.
Results:

- For the serving cell: 56.6%
- For the second best cell: 19.6%
- For the third best cell: 11.4%

This result is not that encouraging, but it must not be forgotten that it often happens that the mobile station finds itself very near the coverage area of the cell but not exactly inside of it. Because of that, it is necessarily to look for the sample position even near the cell coverage. The result below includes the border area of the cell coverage. This border area is about 100 meters.
Results:

- For the serving cell: 74.4%
- For the second best cell: 36.5%
- For the third best cell: 35.2%

As it seems, the result is largely improved by including the border.

This result indicates the good ability of the prediction data.

Now, when the capability of the prediction data has been confirmed, the methods must be developed. These methods allow observing any collected sample regarding its position, serving cell, second best cell and third best cell coverage area as well as their intersection, see pseudo-code Demo1 in Appendix B.

It is also suitable to control any sample-position regarding the different sub-method position estimation, see pseudo-code Demo2 in Appendix B.

By using these sub-methods, which have been described previously, a matrix based on the methods for all the samples could be provided, see pseudo-code Divide_Cell_Size in Appendix B.

By suing results in the matrix comprising different sub-methods, an estimation on the their ability can be assumed. These results are based on estimation error in meter. See pseudo-code **stat2** in Appendix B.

Following tables contain the results of the methods:

**A**

| MAX | MIN | MEDIAN | AVERAGE | STD |
|---|---|---|---|---|
| 2393 | 24 | 353 | 493 | 404 |

**B**

| MAX | MIN | MEDIAN | AVERAGE | STD |
|---|---|---|---|---|
| 4005 | 11 | 713 | 856 | 603 |

**C**

| MAX | MIN | MEDIAN | AVERAGE | STD |
|---|---|---|---|---|
| 4106 | 29 | 868 | 1069 | 761 |

**AB**

| MAX | MIN | MEDIAN | AVERAGE | STD |
|---|---|---|---|---|
| 2000 | 13 | 330 | 428 | 356 |

**AC**

| MAX | MIN | MEDIAN | AVERAGE | STD |
|---|---|---|---|---|
| 2163 | 38 | 355 | 505 | 426 |

**ABC**

| MAX | MIN | MEDIAN | AVERAGE | STD |
|---|---|---|---|---|
| 1367 | 33 | 341 | 433 | 360 |

**ACB**

| MAX | MIN | MEDIAN | AVERAGE | STD |
|---|---|---|---|---|
| 1769 | 67 | 362 | 509 | 448 |

**AB_**

| MAX | MIN | MEDIAN | AVERAGE | STD |
|---|---|---|---|---|
| 1693 | 24 | 277 | 382 | 335 |

**ab_**

| MAX | MIN | MEDIAN | AVERAGE | STD |
|---|---|---|---|---|
| 1992 | 61 | 376 | 489 | 407 |

**AC_**

| MAX | MIN | MEDIAN | AVERAGE | STD |
|---|---|---|---|---|
| 1452 | 44 | 375 | 474 | 346 |

**ac_**

| MAX | MIN | MEDIAN | AVERAGE | STD |
|---|---|---|---|---|
| 2252 | 30 | 432 | 579 | 458 |

**AB|AC**

| MAX | MIN | MEDIAN | AVERAGE | STD |
|---|---|---|---|---|
| 1595 | 32 | 335 | 417 | 324 |

**A|AB**

| MAX | MIN | MEDIAN | AVERAGE | STD |
|---|---|---|---|---|
| 1998 | 26 | 344 | 448 | 355 |

**A|AC**

| MAX | MIN | MEDIAN | AVERAGE | STD |
|---|---|---|---|---|
| 1788 | 38 | 336 | 472 | 372 |

**AB_|AC_**

| MAX | MIN | MEDIAN | AVERAGE | STD |
|---|---|---|---|---|
| 966 | 26 | 236 | 344 | 285 |

**AB_|ab_**

| MAX | MIN | MEDIAN | AVERAGE | STD |
|---|---|---|---|---|
| 1736 | 56 | 299 | 425 | 364 |

**AB_|ac_**

| MAX | MIN | MEDIAN | AVERAGE | STD |
|---|---|---|---|---|
| 1231 | 21 | 261 | 371 | 314 |

**AC_|ac_**

| MAX | MIN | MEDIAN | AVERAGE | STD |
|---|---|---|---|---|
| 1845 | 22 | 408 | 518 | 394 |

**AC_|ab_**

| MAX | MIN | MEDIAN | AVERAGE | STD |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| 1281 | 48 | 248 | 378 | 327 |

**ab_|ac_**

| MAX | MIN | MEDIAN | AVERAGE | STD |
|---|---|---|---|---|
| 1421 | 47 | 279 | 410 | 356 |

**A|AB_**

| MAX | MIN | MEDIAN | AVERAGE | STD |
|---|---|---|---|---|
| 1358 | 14 | 268 | 339 | 269 |

**A|AC_**

| MAX | MIN | MEDIAN | AVERAGE | STD |
|---|---|---|---|---|
| 1917 | 80 | 338 | 394 | 305 |

**A(AB_|AC_)**

| MAX | MIN | MEDIAN | AVERAGE | STD |
|---|---|---|---|---|
| 1039 | 78 | 284 | 350 | 250 |

**MitA-Bneig**

| MAX | MIN | MEDIAN | AVERAGE | STD |
|---|---|---|---|---|
| 1215 | 77 | 298 | 473 | 455 |

**AB-Bneig**

| MAX | MIN | MEDIAN | AVERAGE | STD |
|---|---|---|---|---|
| 1040 | 114 | 499 | 538 | 434 |

**A-Cneig**

| MAX | MIN | MEDIAN | AVERAGE | STD |
|---|---|---|---|---|
| 268 | 66 | 99 | 147 | 80 |

**AC-Cneig**

| MAX | MIN | MEDIAN | AVERAGE | STD |
|---|---|---|---|---|
| 435 | 109 | 349 | 298 | 169 |

**A-betweenB&C**

| MAX | MIN | MEDIAN | AVERAGE | STD |
|---|---|---|---|---|
| 2393 | 24 | 345 | 467 | 379 |

To consider these results it is clear that some of the methods are better then the others. Other problem is that each method gives a better estimate on a specific area, for example in **A-Cneig** the maximum error estimate is the best result among the other but A|**AB**_ gives the best minimum estimated value. Beside non-of these method estimate a position for all the samples but **A.**

Regarding the previous discussion, it is clear that some sub methods gives the best position estimate for different kind of samples. A smart way to classified samples is to divide them in different classes regarding to the size of their serving cell. After that for each class of samples, the best sub method to position them should be founds out. By removing the positioned sample and repeat the same procedure, until all samples have been positioned, a positioning algorithm for each class of samples forms. By putting together all these methods in the right order after the size of the serving cell for the samples and their ability the algorithm will be ready to be used. Here is the result on for different algorithms:

According to a first algorithm, the samples are divided in *four* different groups according to their serving cell size. As it has been described earlier, the sub-methods have been chosen after their ability to give the best possible estimations.

Following is the results:

0<serving cell size<20
Sub method order: **A-Cneig A-Bneig ACB AB_|AC_ A|AB A|AC AbetweenB&C AB_ AC_|ac_ A**

20<serving cell size<65
Sub method order: **AB|AC ABC ACB AC AB_ A**

65<serving cell size<150
Sub method order: **AB|AC ACB AB_|AC_ AB_|ac_ AB_ A|AC AB**

**A**

150<serving cell size<500

Sub method order: **AB_ AB|AC ABC A|AC AB A**

| MAX | MIN | MEDIAN | AVERAGE | STD |
|---|---|---|---|---|
| 2000 | 69 | 387 | 503 | 371 |

These results are produced a method according to pseudo-code ALG1, in Appendix B.

According to a second algorithm, as for the previous algorithm, the samples are divided in *four* different groups according to their serving cell size. The sub-methods have been chosen after their ability to give the best possible estimations.

The results are:

0<serving cell size<20

Sub method order: **ABC A-Cneig AC-Cneig AB-Bneig AB|AC**
**Abneig A|AC AB_|AC_ A|AB_ AB AC_|ac_ A**

20<serving cell size<65

Sub method order: **AB|AC A|AC ABC A-Cneig AC-Cneig AB**
**Bneig A|AB_ A|AB A|AC_ A**

65<serving cell size<150

Sub method order: **ABC ACB AC_ AB|AC A|AB_ A|AC B**

150<serving cell size<500

Sub method order: **ABC AB|AC AB-Bneig AB_ A|AC_ AB A|AC**
**A**

| MAX | MIN | MEDIAN | AVERAGE | STD |
|---|---|---|---|---|
| 1810 | 69 | 408 | 490 | 335 |

These results are produced by pseudo-code ALG2, in Appendix B.

According to a third algorithm, as per the two previous algorithms, the samples have been divided in three different groups and sub-methods have been chosen after their ability to estimate the best position for the samples.

The results are:

0<serving cell size<40
Sub method order: **A-Cneig A|AB_ AB-Bneig ABC AB|AC A|AC A|AB A|AC_ A**

40<serving cell size<110
Sub method order: **A-Cneig ACB A|AC_ AB A|AB_ A|AC A**

110<serving cell size<500
Sub method order: **AB|AC ABC A|AB_ A|AC A|AC_ AB-Bneig AB A**

| MAX | MIN | MEDIAN | AVERAGE | STD |
|---|---|---|---|---|
| 2000 | 31 | 415 | 506 | 415 |

These results are produced by a method according to pseudo-code ALG3, in Appendix B.

According to the fourth algorithm, as per the previous algorithms, the samples are divided in *four* different groups and the sub-methods have been chosen after their ability to give the best possible estimations.

The results are:

0<serving cell size<20
Sub method order: **ACB A-Cneig AB-Bneig A-Bneig A|AB A|AB_ A|AC AC_|ac_ A**

20<serving cell size<60

Sub method order: **A-Cneig AB|AC ABC ACB AC AB-Bneig A|AB A|AB_ A|AC_ A**

60<serving cell size<110

Sub method order: **AC_ AB|AC ACB A|AB_ A|AC A**

110<serving cell size<500

Sub method order: **A|AB_ ABC ACB AB-Bneig AB|AC A|AC A|AC_ A-betweenB&C AB A**

| MAX | MIN | MEDIAN | AVERAGE | STD |
|---|---|---|---|---|
| 2000 | 69 | 392 | 479 | 349 |

These results are produced by pseudo-code ALG4, in Appendix B.

To summarize these results and compare it with GT-1 with TA and GT-1 without TA. The result are illustrate in the following table:

| | MAX | MIN | MEDIAN | AVERAGE | STD |
|---|---|---|---|---|---|
| **Minimum possible** | 1643 | 24 | 260 | 323 | 256 |
| **ALG1** | 2000 | 69 | 387 | 503 | 371 |
| **ALG2** | 1810 | 69 | 408 | 490 | 335 |
| **ALG3** | 2000 | 31 | 415 | 506 | 415 |
| **ALG4** | 2000 | 69 | 392 | 479 | 349 |
| **GT-1 with TA** | 2637 | 53 | 502 | 700 | 474 |
| **GT-1 without TA** | 5026 | 25 | 711 | 827 | 729 |

The *minimum possible* gives the best-estimated positions that are possible with the sub-methods, in other words, the limit of positioning with these methods. As it clears from the table, the fourth

algorithm gives the best result. These results are based on 77 samples only for which data is available on GT-1. The table below shows the result only for ALG1-ALG4.

| | MAX | MIN | MEDIAN | AVERAGE | STD |
|---|---|---|---|---|---|
| **Minimum possible** | 1643 | 11 | 165 | 264 | 269 |
| **ALG1** | 2000 | 26 | 309 | 404 | 340 |
| **ALG2** | 1810 | 13 | 295 | 395 | 329 |
| **ALG3** | 2000 | 14 | 315 | 402 | 330 |
| **ALG4** | 2000 | 14 | 295 | 391 | 333 |

The results are based on 218 samples. It clears from the table that the result becomes better due to more samples. See also the table of Appendix A for more comparisons.

It is clear from previous discussion, positioning by prediction data gives a very good positioning result. Considering the quantity of the available information, it is clear that the result is encouraging. An average error of 391 meters and a standard divination of 333 meters is a very good result. To compare with the existing positioning unit available, the improvement is a fact. In average, **ALG4** improves the positioning compare to *GT1-without TA* by 61% and compare to *GT1-with TA* by 54%. Even the maximum estimated error is improving prominent by 3000 meters comparing GT1-without TA and by 600 meters comparing GT1-with TA. Of course there is long way to go to improve these results but the main obstacle have been removed. A working environment has been provided and different methods of collecting data and handling them has been set. Everything is prepared. Next step will be easy, to make different methods and observing the relation between different available data from the collected samples will surly gives a desirable results.

Finally, the method of the invention is a new way of positioning and the opportunities are a lot. There are numbers of way to improve this method. Maybe the important improvement regarding this report is to increase the number of samples. Reminding that there have been only 219 available samples to base these algorithms on and by dividing the samples in three or four different groups regarding their serving cell sizes, the result will be less certain.

Beside the importance of the numbers of samples, there are many other available parameters that could improve this way of positioning and they have not been taken under consideration here.

- The power control levels (RX levels) received from the mobile station is one of them. RX levels could help, for example, to appoint the importance of which cell or cell combinations should have a greater weight in the estimation of the mobile station position.
- Another source of information is the other of the cell-IDs that are available on each sample. It might be of interest to find out when or how these cell-IDs could help to improve the algorithms. The relation between the detected cells in between could even play an important roll for the positioning algorithms.
- The position of the BTSs toward each other could indicate on how the intersections between the cells could be chosen or which cells are of no importance or which cell is of more importance. By doing more research on this area it surely arise even more ideas to handle the available information and improve the positioning algorithms.

The invention is not limited to the shown embodiments; it can be varied in a number of ways without departing from the scope of the appended claims, and the arrangement and the method can be implemented in various ways depending on the application, functional units, needs and requirements etc. Moreover, the pseudo-codes of Appendix B are given as examples for simplifying the understanding of the invention; hence, other similar procedures can be used to carry out the invention.

APPENDIX A

| Cell Size | Cell ID only | Minimum | ALG1 | ALG2 | ALG3 | ALG4 | Without TA | With TA |
|---|---|---|---|---|---|---|---|---|
| 1 | 126 | 44 | 134 | 134 | 165 | 165 | | |
| 2 | 352 | 289 | 352 | 352 | 323 | 352 | | |
| 2 | 50 | 13 | 26 | 13 | 26 | 26 | | |
| 2 | 56 | 24 | 74 | 74 | 24 | 24 | | |
| 3 | 99 | 99 | 99 | 99 | 99 | 99 | | |
| 3 | 123 | 54 | 123 | 54 | 54 | 54 | | |
| 3 | 94 | 59 | 94 | 94 | 94 | 94 | | |
| 3 | 77 | 77 | 77 | 77 | 106 | 77 | | |
| 4 | 78 | 14 | 125 | 125 | 14 | 14 | | |
| 4 | 66 | 66 | 66 | 66 | 66 | 66 | | |
| 4 | 98 | 29 | 67 | 67 | 29 | 67 | | |
| 6 | 433 | 227 | 433 | 327 | 327 | 327 | 331 | 126 |
| 7 | 104 | 104 | 104 | 104 | 104 | 104 | | |
| 7 | 140 | 113 | 125 | 113 | 125 | 125 | | |
| 7 | 118 | 117 | 137 | 137 | 117 | 117 | | |
| 8 | 677 | 428 | 658 | 644 | 658 | 658 | | |
| 8 | 426 | 91 | 174 | 174 | 268 | 268 | | |
| 8 | 254 | 92 | 238 | 223 | 238 | 238 | | |
| 8 | 356 | 356 | 370 | 397 | 370 | 370 | | |
| 9 | 327 | 95 | 327 | 327 | 327 | 327 | | |
| 9 | 154 | 29 | 99 | 29 | 29 | 29 | | |
| 9 | 28 | 28 | 225 | 107 | 107 | 107 | | |
| 9 | 116 | 38 | 116 | 116 | 124 | 116 | 190 | 159 |
| 10 | 24 | 24 | 55 | 134 | 134 | 55 | | |
| 10 | 67 | 38 | 125 | 84 | 84 | 125 | | |
| 10 | 143 | 45 | 63 | 45 | 63 | 63 | | |
| 10 | 143 | 33 | 87 | 33 | 87 | 87 | | |
| 10 | 183 | 146 | 265 | 265 | 265 | 265 | | |
| 10 | 175 | 26 | 26 | 26 | 81 | 81 | | |
| 10 | 333 | 94 | 94 | 94 | 247 | 94 | | |
| 11 | 139 | 32 | 44 | 32 | 32 | 44 | | |
| 11 | 274 | 133 | 236 | 249 | 190 | 190 | | |
| 11 | 300 | 113 | 241 | 191 | 241 | 241 | | |
| 11 | 41 | 41 | 149 | 56 | 56 | 56 | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 11 | 102 | 81 | 113 | 81 | 81 | 113 | | |
| 11 | 209 | 127 | 273 | 230 | 127 | 127 | | |
| 11 | 146 | 68 | 95 | 68 | 68 | 68 | | |
| 11 | 175 | 175 | 175 | 175 | 175 | 175 | | |
| 11 | 108 | 47 | 82 | 94 | 153 | 153 | | |
| 12 | 145 | 122 | 143 | 230 | 216 | 143 | | |
| 12 | 89 | 89 | 89 | 287 | 287 | 287 | | |
| 12 | 122 | 107 | 114 | 114 | 114 | 114 | | |
| 13 | 468 | 350 | 408 | 469 | 469 | 408 | | |
| 13 | 177 | 177 | 241 | 241 | 241 | 241 | | |
| 13 | 217 | 85 | 212 | 212 | 323 | 323 | | |
| 13 | 181 | 132 | 192 | 192 | 256 | 192 | | |
| 13 | 181 | 64 | 181 | 72 | 72 | 72 | | |
| 13 | 238 | 98 | 118 | 118 | 113 | 113 | | |
| 13 | 254 | 174 | 236 | 236 | 174 | 174 | | |
| 13 | 473 | 310 | 421 | 370 | 421 | 421 | 561 | 201 |
| 14 | 95 | 95 | 143 | 193 | 143 | 143 | | |
| 14 | 240 | 214 | 240 | 240 | 240 | 240 | | |
| 14 | 250 | 86 | 260 | 260 | 166 | 166 | | |
| 15 | 257 | 22 | 63 | 63 | 171 | 171 | | |
| 17 | 908 | 81 | 450 | 450 | 638 | 638 | | |
| 17 | 533 | 151 | 241 | 241 | 425 | 425 | | |
| 17 | 94 | 68 | 94 | 94 | 94 | 94 | | |
| 17 | 832 | 775 | 801 | 862 | 775 | 801 | 725 | 1,051 |
| 17 | 1,262 | 1,262 | 1,262 | 1,262 | 1,262 | 1,262 | | |
| 17 | 954 | 879 | 1,014 | 879 | 879 | 879 | | |
| 18 | 182 | 92 | 121 | 121 | 206 | 121 | | |
| 18 | 268 | 135 | 268 | 268 | 268 | 268 | | |
| 18 | 298 | 114 | 298 | 114 | 114 | 114 | | |
| 18 | 215 | 215 | 928 | 928 | 670 | 670 | 334 | 358 |
| 19 | 345 | 112 | 321 | 261 | 261 | 321 | | |
| 19 | 234 | 124 | 293 | 293 | 124 | 124 | | |
| 19 | 311 | 86 | 86 | 86 | 103 | 86 | | |
| 19 | 170 | 108 | 137 | 188 | 188 | 137 | | |
| 19 | 280 | 21 | 41 | 41 | 196 | 196 | 85 | 242 |
| 21 | 505 | 505 | 505 | 600 | 600 | 600 | | |
| 22 | 397 | 393 | 533 | 393 | 393 | 393 | | |
| 25 | 1,338 | 1,074 | 1,595 | 1,595 | 1,367 | 1,595 | | |
| 26 | 526 | 178 | 280 | 295 | 295 | 295 | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 26 | 396 | 56 | 87 | 240 | 240 | 240 | | |
| 26 | 598 | 164 | 366 | 452 | 230 | 366 | 617 | 344 |
| 27 | 256 | 107 | 256 | 107 | 107 | 107 | 1,008 | 150 |
| 27 | 178 | 73 | 91 | 73 | 459 | 91 | 70 | 53 |
| 27 | 136 | 136 | 136 | 176 | 176 | 176 | 211 | 286 |
| 28 | 70 | 70 | 347 | 176 | 176 | 176 | | |
| 28 | 162 | 162 | 162 | 301 | 301 | 301 | 159 | 598 |
| 30 | 103 | 103 | 266 | 178 | 417 | 266 | | |
| 30 | 193 | 39 | 39 | 39 | 84 | 39 | | |
| 30 | 845 | 844 | 845 | 929 | 929 | 929 | 430 | 430 |
| 31 | 415 | 124 | 265 | 336 | 235 | 265 | | |
| 31 | 464 | 176 | 196 | 318 | 318 | 318 | | |
| 31 | 374 | 217 | 374 | 293 | 293 | 293 | | |
| 31 | 253 | 77 | 188 | 188 | 188 | 188 | | |
| 31 | 336 | 11 | 229 | 229 | 229 | 229 | | |
| 31 | 346 | 96 | 217 | 217 | 96 | 217 | | |
| 33 | 318 | 123 | 123 | 123 | 149 | 123 | | |
| 33 | 233 | 63 | 233 | 244 | 244 | 244 | | |
| 33 | 200 | 46 | 187 | 187 | 85 | 187 | | |
| 33 | 766 | 569 | 670 | 702 | 702 | 702 | | |
| 33 | 350 | 248 | 350 | 268 | 268 | 268 | | |
| 33 | 158 | 106 | 244 | 244 | 328 | 244 | | |
| 33 | 354 | 348 | 354 | 351 | 351 | 351 | 714 | 502 |
| 33 | 290 | 290 | 290 | 322 | 322 | 322 | 504 | 577 |
| 33 | 65 | 45 | 160 | 160 | 160 | 160 | 836 | 364 |
| 33 | 208 | 59 | 74 | 74 | 59 | 74 | 199 | 361 |
| 33 | 447 | 295 | 343 | 343 | 295 | 343 | 290 | 936 |
| 35 | 406 | 122 | 406 | 249 | 249 | 249 | | |
| 35 | 518 | 97 | 227 | 227 | 129 | 227 | | |
| 35 | 395 | 254 | 395 | 477 | 477 | 477 | | |
| 35 | 153 | 153 | 521 | 228 | 228 | 228 | | |
| 35 | 226 | 226 | 451 | 338 | 338 | 451 | | |
| 37 | 196 | 155 | 164 | 155 | 197 | 164 | | |
| 37 | 231 | 231 | 231 | 286 | 286 | 286 | | |
| 37 | 338 | 55 | 462 | 396 | 55 | 462 | 25 | 271 |
| 37 | 732 | 685 | 732 | 745 | 745 | 745 | 1,026 | 489 |
| 37 | 341 | 178 | 341 | 259 | 259 | 259 | 434 | 581 |
| 37 | 277 | 247 | 318 | 318 | 318 | 318 | 501 | 285 |
| 37 | 559 | 253 | 740 | 504 | 504 | 504 | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 37 | 150 | 150 | 359 | 239 | 239 | 239 | 186 | 186 |
| 39 | 402 | 402 | 402 | 406 | 406 | 406 | | |
| 40 | 249 | 111 | 188 | 188 | 188 | 188 | | |
| 46 | 172 | 172 | 292 | 292 | 292 | 292 | | |
| 46 | 312 | 63 | 231 | 231 | 231 | 231 | | |
| 46 | 134 | 134 | 281 | 281 | 281 | 281 | | |
| 46 | 1,215 | 941 | 1,215 | 1,040 | 1,040 | 1,040 | 1,548 | 998 |
| 48 | 377 | 246 | 377 | 246 | 253 | 246 | 214 | 612 |
| 48 | 328 | 284 | 328 | 284 | 291 | 284 | 408 | 164 |
| 48 | 132 | 31 | 132 | 77 | 31 | 77 | 778 | 55 |
| 51 | 613 | 371 | 371 | 411 | 396 | 411 | | |
| 51 | 620 | 224 | 224 | 360 | 360 | 360 | | |
| 51 | 533 | 198 | 533 | 228 | 228 | 228 | | |
| 51 | 835 | 24 | 765 | 800 | 421 | 765 | | |
| 51 | 841 | 771 | 827 | 827 | 827 | 827 | 684 | |
| 51 | 371 | 340 | 340 | 340 | 340 | 340 | 301 | 124 |
| 51 | 646 | 177 | 646 | 236 | 778 | 236 | 923 | 368 |
| 51 | 188 | 60 | 218 | 218 | 218 | 218 | 910 | 812 |
| 51 | 504 | 286 | 504 | 286 | 418 | 286 | 803 | 474 |
| 51 | 254 | 254 | 305 | 312 | 505 | 305 | 253 | 446 |
| 51 | 458 | 424 | 424 | 424 | 424 | 424 | | |
| 51 | 278 | 233 | 233 | 246 | 265 | 233 | | |
| 53 | 167 | 60 | 200 | 200 | 200 | 167 | | |
| 54 | 795 | 394 | 795 | 579 | 1,063 | 579 | | |
| 55 | 286 | 90 | 90 | 188 | 428 | 90 | 768 | 272 |
| 55 | 206 | 107 | 206 | 154 | 270 | 154 | 571 | 301 |
| 55 | 339 | 33 | 69 | 69 | 69 | 69 | | |
| 56 | 557 | 329 | 329 | 408 | 418 | 329 | | |
| 57 | 772 | 670 | 772 | 810 | 670 | 810 | 1,757 | 578 |
| 58 | 277 | 133 | 201 | 201 | 201 | 201 | 682 | 409 |
| 64 | 315 | 315 | 315 | 315 | 315 | 315 | 200 | 361 |
| 66 | 402 | 237 | 272 | 272 | 272 | 272 | | |
| 66 | 246 | 193 | 331 | 331 | 331 | 331 | | |
| 66 | 472 | 264 | 475 | 314 | 277 | 314 | | |
| 66 | 336 | 313 | 444 | 444 | 444 | 444 | | |
| 66 | 732 | 260 | 313 | 313 | 313 | 313 | 1,108 | 918 |
| 66 | 462 | 66 | 104 | 429 | 377 | 429 | 1,003 | 628 |
| 69 | 597 | 110 | 110 | 163 | 347 | 163 | | |
| 69 | 708 | 201 | 515 | 201 | 433 | 201 | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 69 | 399 | 398 | 398 | 398 | 398 | 398 | 230 | 227 |
| 70 | 984 | 136 | 136 | 435 | 435 | 435 | 665 | 665 |
| 70 | 1,266 | 924 | 1,112 | 1,112 | 1,112 | 1,112 | | 677 |
| 71 | 460 | 335 | 758 | 758 | 758 | 758 | | |
| 71 | 483 | 65 | 719 | 423 | 423 | 423 | | |
| 71 | 521 | 220 | 780 | 780 | 780 | 780 | | |
| 71 | 841 | 108 | 108 | 474 | 474 | 474 | | |
| 71 | 1,161 | 482 | 531 | 537 | 841 | 537 | 1,446 | 764 |
| 74 | 1,582 | 586 | 1,137 | 1,358 | 1,358 | 1,358 | 1,152 | 1,152 |
| 76 | 556 | 288 | 439 | 548 | 439 | 439 | 1,750 | 887 |
| 77 | 1,193 | 887 | 887 | 970 | 970 | 970 | 162 | 338 |
| 77 | 944 | 814 | 814 | 1,810 | 814 | 944 | 313 | 190 |
| 77 | 816 | 526 | 835 | 526 | 578 | 526 | 344 | 344 |
| 77 | 329 | 329 | 379 | 379 | 379 | 379 | 816 | 1,596 |
| 77 | 629 | 629 | 801 | 801 | 801 | 801 | 939 | 1,684 |
| 77 | 509 | 153 | 465 | 465 | 465 | 465 | 1,030 | 649 |
| 77 | 433 | 193 | 295 | 295 | 295 | 295 | 120 | 208 |
| 78 | 295 | 128 | 196 | 141 | 196 | 196 | | |
| 78 | 171 | 171 | 258 | 467 | 258 | 258 | | |
| 78 | 479 | 151 | 810 | 226 | 226 | 226 | 1,482 | 204 |
| 78 | 319 | 24 | 379 | 379 | 379 | 379 | 388 | 1,079 |
| 82 | 292 | 228 | 488 | 488 | 488 | 488 | | |
| 83 | 544 | 315 | 415 | 315 | 315 | 315 | 1,185 | 881 |
| 92 | 1,039 | 292 | 720 | 720 | 720 | 720 | 559 | 1,800 |
| 92 | 163 | 163 | 199 | 392 | 199 | 199 | 844 | 394 |
| 92 | 463 | 463 | 584 | 747 | 584 | 584 | 998 | 1,043 |
| 103 | 1,117 | 802 | 802 | 842 | 842 | 842 | 1,941 | 1,728 |
| 104 | 686 | 340 | 387 | 387 | 387 | 387 | 1,090 | 2,637 |
| 104 | 1,032 | 128 | 128 | 452 | 452 | 452 | 971 | 766 |
| 104 | 485 | 145 | 145 | 146 | 145 | 145 | | |
| 104 | 691 | 234 | 395 | 431 | 395 | 395 | | |
| 104 | 1,012 | 149 | 149 | 433 | 433 | 433 | | |
| 104 | 788 | 719 | 964 | 978 | 964 | 964 | | |
| 115 | 2,393 | 680 | 1,588 | 1,452 | 1,917 | 1,917 | | |
| 118 | 667 | 278 | 278 | 415 | 415 | 415 | | |
| 118 | 690 | 295 | 463 | 295 | 463 | 295 | | |
| 118 | 631 | 358 | 358 | 418 | 418 | 418 | 640 | 217 |
| 118 | 701 | 701 | 1,693 | 842 | 842 | 842 | 5,026 | 1,634 |
| 126 | 631 | 281 | 367 | 367 | 367 | 367 | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 136 | 895 | 651 | 795 | 651 | 795 | 795 | | |
| 136 | 895 | 651 | 795 | 651 | 795 | 795 | | |
| 136 | 825 | 563 | 707 | 775 | 707 | 775 | | |
| 136 | 856 | 611 | 1,148 | 799 | 1,148 | 799 | | |
| 136 | 1,005 | 166 | 166 | 444 | 444 | 444 | | |
| 136 | 1,423 | 467 | 1,294 | 1,294 | 1,294 | 1,294 | | |
| 145 | 2,024 | 1,643 | 2,000 | 1,643 | 2,000 | 2,000 | | |
| 166 | 336 | 336 | 690 | 690 | 690 | 690 | 1,537 | 446 |
| 166 | 77 | 77 | 347 | 692 | 347 | 692 | 514 | 627 |
| 166 | 633 | 253 | 253 | 253 | 253 | 253 | 682 | 920 |
| 166 | 642 | 562 | 562 | 562 | 562 | 562 | 599 | 360 |
| 166 | 814 | 415 | 415 | 415 | 415 | 415 | | |
| 166 | 463 | 392 | 726 | 726 | 392 | 392 | 738 | 692 |
| 166 | 827 | 650 | 650 | 793 | 793 | 793 | | |
| 213 | 881 | 678 | 678 | 678 | 678 | 678 | 621 | 623 |
| 213 | 1,065 | 91 | 397 | 91 | 397 | 91 | 1,001 | 646 |
| 213 | 809 | 477 | 477 | 477 | 477 | 477 | | |
| 243 | 1,119 | 160 | 737 | 737 | 737 | 737 | 990 | 403 |
| 269 | 1,446 | 451 | 498 | 498 | 971 | 971 | 1,913 | 257 |
| 269 | 1,040 | 365 | 780 | 780 | 780 | 780 | 1,811 | 1,169 |
| 269 | 1,022 | 755 | 755 | 755 | 755 | 755 | | |
| 392 | 1,463 | 103 | 103 | 295 | 295 | 295 | | |
| 392 | 1,603 | 88 | 939 | 88 | 939 | 88 | | |
| 392 | 1,696 | 242 | 403 | 341 | 403 | 341 | 526 | 540 |
| 441 | 1,459 | 1,459 | 1,459 | 1,459 | 1,459 | 1,459 | 2,076 | 1,265 |
| 441 | 874 | 214 | 375 | 1,102 | 375 | 1,102 | 731 | 834 |
| 484 | 1,367 | 1,165 | 1,197 | 1,165 | 1,197 | 1,165 | 2,885 | 1,117 |
| 484 | 1,485 | 606 | 953 | 637 | 637 | 637 | 877 | 532 |
| | **Cell ID** | **Minimum** | **ALG1** | **ALG2** | **ALG3** | **ALG4** | **Without TA** | **With TA** |
| **sum** | 46,144 | 24,853 | 38,735 | 37,768 | 38,957 | 36,853 | 63,939 | 48,265 |
| **Average** | 599 | 323 | 503 | 490 | 506 | 479 | 827 | 700 |
| **max** | 2,393 | 1,643 | 2,000 | 1,810 | 2,000 | 2,000 | 5,026 | 2,637 |
| **min** | 77 | 24 | 69 | 69 | 31 | 69 | 25 | 53 |
| **STD** | 393 | 256 | 371 | 335 | 352 | 349 | 729 | 474 |
| **median** | 533 | 260 | 387 | 408 | 415 | 392 | 711 | 502 |
| **Number of Cell** | 77 | 77 | 77 | 77 | 77 | 77 | 77 | 77 |

| | Cell ID | Minimum | ALG1 | ALG2 | ALG3 | ALG4 |
|---|---|---|---|---|---|---|
| sum | 107,559 | 57,597 | 88,175 | 85,682 | 87,689 | 85,279 |
| Average | 493 | 264 | 404 | 393 | 402 | 391 |
| max | 2,393 | 1,643 | 2,000 | 1,810 | 2,000 | 2,000 |
| min | 24 | 11 | 26 | 13 | 14 | 14 |
| STD | 404 | 269 | 340 | 329 | 330 | 333 |
| Median | 353 | 165 | 309 | 295 | 315 | 295 |
| Number of Cell | 218 | 218 | 218 | 218 | 218 | 218 |

## APPENDIX B

### Modification of Raw Data:

*Adjust*

% Function Adjust modifies the raw sample data in to coordinates, cell-IDs and the RX-levels (if available).

%

% input : D "file" the raw data of samples.

% output: d "matrix" the modifide samlpe data.

*Prediction_Modific*

% Function Prediction_Modific modifide and adjust the raw data of prediction file to a matrix.

% input : infile "File" The raw data of prediction file.

% output: o "matrix" The modifide matrix of prediction file

*Raw_to_Modific*

% Function Raw_to_Modific consider the raw sample data (infile) and modifies and writes in a file (out file). In the last stage, rechanges the result from hex-code to decimal inside a matrix "D".

%

% input : infile "File" Raw data

% outfile "File" Modified data

%

% output: D "Matrix" Cell_IDs & RX_leves

### Main Programs

*ALG1*

% Function ALG1 choose positioning data from the T file regarding to the cell size & the combination that has been chosen.

%

% 0>X>20 :mitA-Cg mitA-Bg ACB AB_|AC_ A|AB A|AC mitAdåAmellanBoC

% AB_ AC_|ac_ A

%............................................................
% 20>X>65 :AB|AC ABC ACB AC AB_ A
%............................................................
% 65>X>150 :AB|AC ACB AB_|AC_ AB_|ac_ AB_ A|AC AB A
%............................................................
% 150>X>500 :AB_ AB|AC ABC A|AC AB A

*ALG2*

% Function ALG2 choose positioning data from the T file regarding to the cell size & the combination that has been chosen.
%
% 0>X>20 :ABC mitA-Cg mitAC-Cg mitAB-Bg AB|AC mitA-Bg A|AC AB_|AC_
% A|AB_ AB AC_|ac_ A
%............................................................
% 20>X>65 :AB|AC A|AC ABC mitA-Cg mitAC-Cg mitAB-Bg A|AB_ A|AB
% A|AC_ A
%............................................................
% 65>X>150 :ABC ACB AC_ AB|AC A|AB_ A|AC B
%............................................................
% 150>X>500 :ABC AB|AC mitAB-Bg AB_ A|AC_ AB A|AC A

*ALG3*

% Function ALG3 choose positioning data from the T file regarding to the cell size & the combination that has been chosen.
%
% 0>X>40 :mitA-Cg A|AB_ mitAB-Bg ABC AB|AC A|AC A|AB A|AC_ A
%............................................................
% 40>X>110 :mitA-Cg ACB A|AC_ AB A|AB_ A|AC A
%............................................................
% 110>X>500 :AB|AC ABC A|AB_ A|AC A|AC_ mitAB-Bg AB A

*ALG4*

% Function ALG4 choose positioning data from the T file regarding to the cell size & the combination that has been chosen.

%

% 0>X>20 :ACB mitA-Cg mitAB-Bg mitA-Bg A|AB A|AB_ A|AC AC_|ac_ A

%..............................................................

% 20>X>60 :mitA-Cg AB|AC ABC ACB AC mitAB-Bg A|AB A|AB_A|AC_ A

%..............................................................

% 60>X>110 :AC_ AB|AC ACB A|AB_ A|AC A

%..............................................................

% 110>X>500 :A|AB_ ABC ACB mitAB-Bg AB|AC A|AC A|AC_ mitA-midBoC AB A

Cell_Ability

% Function Cell_Ability find out statistics on how good the cell combination covers the sample data.

%

% input : P "matrix" prediction file

% S "matrix" sample data

*Divide_Cell_Size*

% Function Divide_cell_size divides the matrix provided by Result_matrix, which containes result on al sub methods. This divided parts then used stat1 to give the statistic of the cell groups.

%

% input : T "matrix"

%

% output: Tam "matrix"

*Metod1*

% Function metod1 for: 'k=1' evaluates middle coordinates of the A

% for each sample with the cell size.

% 'k=02' evaluates middle coordinates of the B

% for each sample with the cell size.

% 'k=003' evaluates middle coordinates of the C

% for each sample with the cell size.

% 'k=12' evaluates middle coordinates of the

% intersection A & B.
% 'k=13' evaluates middle coordinates of the
% intersection A & C, C as 2:nd best cell.
% 'k=123' evaluates middle coordinates of the
% intersection A, B & C.
% 'k=132' evaluates middle coordinates of the
% intersection A, C, as 2:nd best cell &
% B, as third best cell.
%
% input: P "matrix" P-file
% S "matrix" sample data
% k "integer"
%
% output: C "matrix" coordinates & cell
% intersection size

*Metod2*

% Function metod3 evaluats for 'l=12' If no intersection between A & B, middle of nearest point of B due to A and nearest point of B due to middle of A.
% 'l=13' If no intersection between A &
% C, middle of nearest point of C
% due to A and nearest point of C
% due to middle of A.
%
% input : P "matrix " prediction file.
% S "matrix " sample file.
% l "integer" condition
%
% output: near "vector" result on nearest of B or C due to middle of A.
% mid "vector" result on middle of nearest point of B or C due to the % nearest point of A due to B or C.

*Metod3*

% Function metod4 finds the samples in which the cells are neighbours.

% for 'l=12' looks among A & B
% 'l=13' looks among A & C as 2:nd best cell
% 'l=123' looks among A & B & C
% 'l=1' looks among A & one or more if the other cells
% In all cases the combination most be true. In the last one if A
% matches with any of the other cells it will be true.
%
% input : S "matrix" sample data.
%
% output: C "vector" with position of the matched cells .

*Metod4*

% Function metod5 finds out if A is in the middle of B & C.
%
% input : A, B, C "xy-coordinates"
%
% output: L "matrix"

*Resultat_Matrix*

% Function Resultat_Matrix makes a matrix of different sub methods.
% Each sub method owns four columns: x-coordinate
% y-coordinate
% size of the cells/ cell
% combination estimated error
%
% input : P "matrix" prediction data
% S "matrix" sample data
%
% output: Mat" matrix" the result of all sub methods.

*Stat2*

% Function Stat2 evaluates, in vector "T", median, error at 67%, 80% and 90%. Beside it gives in '%' number of error less then 71 meters & 142 meters.
%

% input : T "vector"

%

% output: medi, p67, p80, p90, p142 & p71

**Sub Programs**

*decTOhex*

% Function decTOhex change a vector of decimal number to hexadecimal, by changing the first three digits to hex . the last digit changes to A if 1, B if 2 and C if 3.

%

% input : ID "vector" A vector of decimal numbers.

% output: D "vector" A column of hexadecimals.

*FindCell*

% Function FindCell find the best, second best, the third best choice of cell ID in the Matrix P or a chosen combination.

% input:

% bas "vector" Chosen Cell_ID/ID-combination as a vector.

% ex: as the serving cell--> [Cell_ID].

% P "matrix" Which one can find the combinations.

% l "vector" cell placement

% output:

% T "matrix" Result of the chosen combination in P.

*FindSamCell*

% Function FindSamCell choose the row in S with its cell combination and finds the match data in P due to the cell combination.

% input : P "matrix" referred data.

% S "matrix" where cell combination will be chosen.

% row "integer" The row inside S.

% cell "vector" Cell combination as a vector.

% output: T "matrix" Result matrix.

% Sid "vector" Cell_ID/IDs in sample data.

*FpredCoord*

% Function FpredCoord finds the predicted data from the prediction file regarding to the sample data based on Coordinates.

%

% input : Matrix P (The prediction file)

% Matrix S (The sample file)

% Integer nr (The row of sample matrix)

% output: Matrix T (Part of prediction file associated to sample matrix)

% Vector Srx RX-levels in the chosen sample row.

% vector Sid Cell_IDs related to the sample row.

*Grand*

% Function Grand is background function to Demo1. It takes different parameters from main.

% input : P "matrix" prediction matrix.

% S "matrix" sample matrix.

% H "vector" option parameters for different evaluations.

% D "matrix" option parameters for different cell combinations.

% a "integer" figure parameter.

% col "integer" colour parameter.

% mark "integer" marker parameter.

% output: AnsS "matrix" answer matrix of the combination.

% AnsC "matrix" answer matrix of the combination.

*hexTOdec*

% Function hexTOdec change a vector of hexadecimal to decimal number, by changing the first three digits form decimal to hex. The last digit changes if A to 1, if B to 2 and if C to 3

%

% input : ID "vector" A column of hexadecimals.

% output: k "vector" A vector of decimal numbers.

*Middle-XY*

% Function Middle-xy evaluates middle 'xy' coordinate of M and the row size of it.

%

% input : M "matrix"

% output: C "matrix" coordinate & size of M.

*Neig*

% Function Neig find out if the cells in "cell" are neighbours or not.

%

% input : cell "vector " cells that will be look at.

%

% output: con "integer" gives '1' for true & '0' for false.

*Rms*

% Function rms takes the matrix p & q as input and measure the difference between the first and the second rows in p & q by rms method input: p, q as two matrixes output: teta as the difference based on rms method.

*Stat2*

% Function Stat2 evaluates, in vector "T", median, error at 67%, 80% and 90%. Beside it gives in '%' number of error less then 71 meters & 142 meters.

%

% input : T "vector"

%

% output: medi, p67, p80, p90, p142 & p71

**Demo Programs**

*Demo1*

% Function Demo1 is the main function. It's the control panel for manually handling of the simulation & verification of the sample data.

*Demo2*

% Function Demo2 plots all combinations between chosen bas and its neighbours in three different plots. This function even plots the actual position of the sample if the Cell_ID is from the sample

% data.

%

% input : Ans "matrix" Bas compare to it.

% Bas "vector" Cell ID in a vector in its position, ex: as second--> [0 Cell_ID 0].

% form the sample data.

% output: Ans "matrix" same as input Ans.

% AD "vector" Cells involve in the chosen area.

*Demo3*

% Function Demo3 plots the position of the sample as an star "*" and

% other combinations by " A B C AB AC ABC ACB AB_ ab_ AC_ ac_".

## CLAIMS

1. A method of estimating the position of a mobile station in a cellular network, comprising a serving cell and neighboring cells, the method comprising the steps of:

- employing different sub-methods to estimate an actual position of the mobile station, said submethods comprising at least two of:
  - selecting a center of a cell,
  - selecting an intersection of a cell,
  - a middle point of a position in cells,
  - taking an action when no intersection between the serving cell and the a best cell occurs,
- combining said sub-methods with each other with respect to a size of a serving cell,
- dividing the size of said serving cell in a number of different sectors, based on a number of pixels, which every cell is made of a number of pixels, and
- selecting the best sub-methods for each cell-group.

2. The method according to claim 1,
wherein according to a first sub-method a middle of the serving cell is selected as the estimated position of the mobile station.

3. The method according to claim 1,
wherein according to a second sub-method a middle of the second best cell is selected as the estimated position of the mobile station.

4. The method according to claim 1,
wherein according to a third sub-method a middle of the third best cell is chosen as the estimated position of the mobile station.

5. The method according to claim 1,
wherein according to a fourth sub-method an intersection between the serving cell and the second best cell exists, the middle of this intersection is chosen as the estimated position of the mobile station.

6. The method according to claim 1,
wherein according to a fifth sub-method an intersection between the serving cell and the third best cell exists, the middle of this intersection is chosen as the estimated position of the mobile station.

7. The method according to claim 1,
wherein açcording to a sixth sub-method an intersection between the serving cell, the third best cell (as the second best cell) and the second best cell (as the third best cell) exists, the middle of this intersection is selected as the estimated position of the mobile station.

8. The method according to claim 1,
wherein according to a seventh sub-method an intersection between the serving cell, the third best cell (As the second best cell) and the second best cell (As the third best cell) exists, wherein the middle of this intersection is chosen as the estimated position of the mobile station.

9. The method according to claim 1,
wherein according to a eight sub-method when no intersection between the serving cell and the second best cell occur, thus the middle of the two nearest pixels between the serving cell and the second best cell is choose as the estimated position of the mobile station.

10. The method according to claim 1,
wherein according to a ninth sub-method when no intersection between the serving cell and the second best cell occurs, the middle of the nearest pixel in the second best cell regarding the serving cell and the middle of the serving cell is chosen as the estimated position of the mobile station.

11. The method according to claim 1,
wherein according to a tenth sub-method when no intersection between the serving cell and the third best cell occurs, the middle of the two nearest pixels between the serving cell and the second best cell is chosen as the estimated position of the mobile station.

12. The method according to claim 1,
wherein according to a eleventh sub-method when no intersection between the serving cell and the third best cell occurs, the middle of the nearest pixel in the second best cell regarding the

serving cell and the middle of the serving cell is selected as the estimated position of the mobile station.

13. The method according to any of preceding claims,
wherein according to a twelve sub-method a middle point of the position in third and fourth methods is chosen as the position of the mobile station.

14. The method according to any of preceding claims,
wherein according to a thirteenth sub-method a middle point of the position in first and fourth methods is selected as the position of the mobile station.

15. The method according to any of preceding claims,
wherein according to a fourteenth sub-method a middle point of the position in first and fifth methods is chosen as the position of the mobile station

16. The method according to any of preceding claims,
wherein according to a fifteenth sub-method a middle point of the position in eight and tenths methods is chosen as the position of the mobile station.

17. The method according to any of preceding claims,
wherein according to a sixteenth sub-method a middle point of the position in eighth and ninth methods is selected as the position of the mobile station.

18. The method according to any of preceding claims,
wherein according to an seventieth sub-method a middle point of the position in eighth and eleventh methods is chosen as the position of the mobile station

19. The method according to any of preceding claims,
wherein according to an eighteenth sub-method a middle point of the position in tenth and eleventh methods is selected as the position of the mobile station

20. The method according to any of preceding claims,
wherein according to a nineteenth second sub-method a middle point of the position in tenth and ninth methods is chosen as the position of the mobile station.

21. The method according to any of preceding claims,
wherein according to a twentieth sub-method a middle point of the position in ninth and tenth methods is selected as the position of the mobile station.

22. The method according to any of preceding claims,
wherein according to a twenty first sub-method a middle point of the position in first and eighth methods is selected as the position of the mobile station.

23. The method according to any of preceding claims,
wherein according to a twenty second sub-method a middle point of the position in first and tenth methods is selected as the position of the mobile station.

24. The method according to any of preceding claims,
wherein according to a twenty third sub-method a middle point of the position in first and fifteenth methods is selected as the position of the mobile station.

25. The method according to any of preceding claims,
wherein according to a twenty fourth sub-method a middle according to the first method is chosen as the position of the mobile stations; only for samples there second best cell is close to the serving cell.

26. The method according to any of preceding claims,
wherein according to a twenty fifth sub-method the eight sub-method is selected as the position of the mobile stations; only for samples there second best cell is close to the serving cell.

27. The method according to any of preceding claims,
wherein according to a twenty sixth sub-method the first sub-method is selected as the position of the mobile stations, only for samples there third best cell is close to the serving cell.

28. The method according to any of preceding claims,
wherein according to a twenty seventh sub-method the tenth sub-method is selected as the position of the mobile stations, only for samples there third best cell is close to the serving cell.

29. The method according to any of preceding claims,
wherein according to a twenty eighth sub-method the first sub-method is selected as the position of the mobile stations, when the value according to the first sub-method is between the second and third sub-methods.

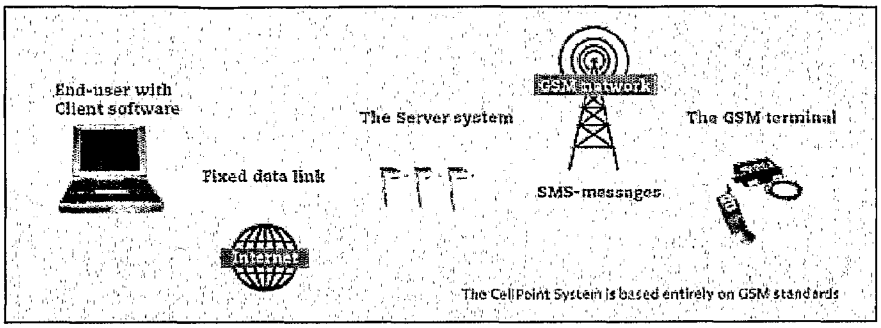

End-user with
Client software
Fixed data link
Internet
The Server system
GSM network
SMS-messages
The GSM terminal
The CellPoint System is based entirely on GSM standards

Fig. 1

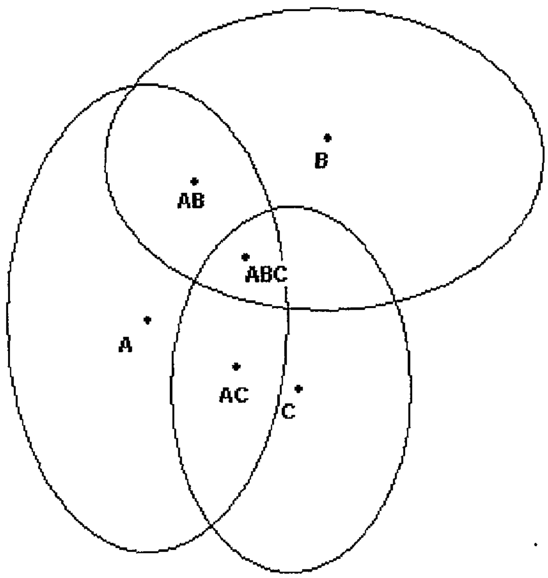

B
AB
ABC
A
AC
C

Fig. 2

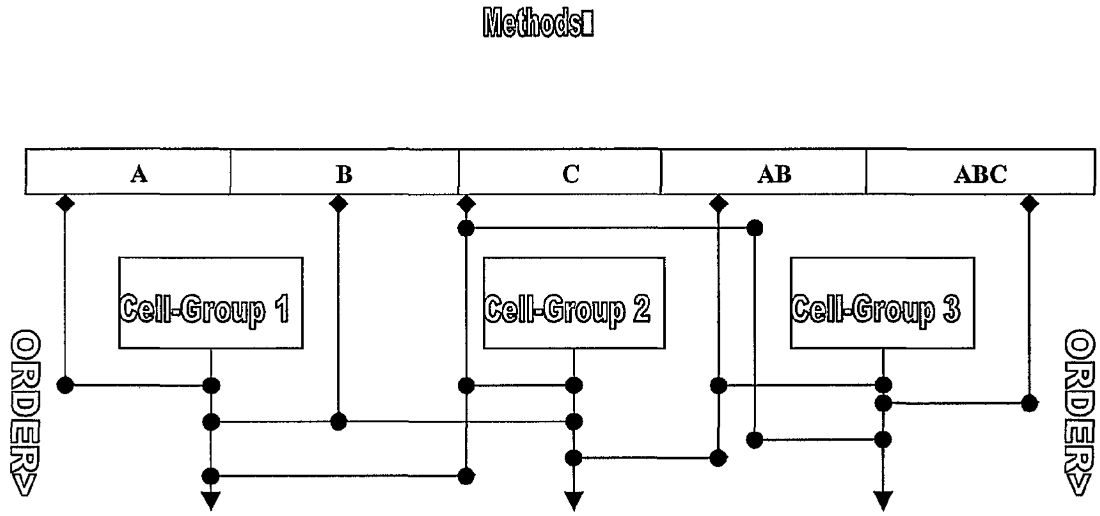

Methods
A
B
C
AB
ABC
Cell-Group 1
Cell-Group 2
Cell-Group 3
ORDER>
ORDER>

Fig. 3

# INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 01/02895

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC7: H04Q 7/38
According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

IPC7: H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| A | WO 9946947 A1 (ERICSSON INC.), 16 Sept 1999 (16.09.99), abstract<br>-- | 1-29 |
| A | WO 9427398 A1 (DENNISON, EVERETT), 24 November 1994 (24.11.94), page 5, line 15 - page 7, line 7<br>-- | 1-29 |
| A | WO 9946950 A1 (ERICSSON, INC), 16 Sept 1999 (16.09.99), figure 3, abstract<br>-- | 1-29 |
| A | WO 9963780 A1 (ERICSSON INC.), 9 December 1999 (09.12.99), abstract<br>-- | 1-29 |

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 5 April 2002 | 30-04-2002 |
| Name and mailing address of the ISA/<br>Swedish Patent Office<br>Box 5055, S-102 42 STOCKHOLM<br>Facsimile No. +46 8 666 02 86 | Authorized officer<br><br>Stefan Hansson /js<br>Telephone No. +46 8 782 25 00 |

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 01/02895

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| A | WO 9955018 A1 (MOTOROLA INC.), 28 October 1999 (28.10.99), abstract | 1-29 |

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# INTERNATIONAL SEARCH REPORT

Information on patent family members

28/01/02

International application No.
PCT/SE 01/02895

| Patent document cited in search report | | | Publication date | Patent family member(s) | | | Publication date |
|---|---|---|---|---|---|---|---|
| WO | 9946947 | A1 | 16/09/99 | AU | 2990799 | A | 27/09/99 |
| | | | | CN | 1300515 | T | 20/06/01 |
| | | | | EP | 1062825 | A | 27/12/00 |
| | | | | US | 6002936 | A | 14/12/99 |
| WO | 9427398 | A1 | 24/11/94 | AU | 6772994 | A | 12/12/94 |
| | | | | US | 5546445 | A | 13/08/96 |
| | | | | US | 5815814 | A | 29/09/98 |
| | | | | US | 5946611 | A | 31/08/99 |
| | | | | US | 6324404 | B | 27/11/01 |
| WO | 9946950 | A1 | 16/09/99 | AU | 2996299 | A | 27/09/99 |
| | | | | BR | 9908647 | A | 14/11/00 |
| | | | | CN | 1292982 | T | 25/04/01 |
| | | | | EE | 200000524 | A | 15/02/02 |
| | | | | EP | 1062827 | A | 27/12/00 |
| | | | | US | 6243588 | B | 05/06/01 |
| WO | 9963780 | A1 | 09/12/99 | AU | 3896399 | A | 20/12/99 |
| | | | | US | 6134447 | A | 17/10/00 |
| | | | | US | 6328666 | B | 11/12/01 |
| WO | 9955018 | A1 | 28/10/99 | EP | 1074095 | A | 07/02/01 |
| | | | | US | 6108558 | A | 22/08/00 |